Atti del V Convegno Internazionale

RECYCLING

Proceedings of the 5th International Conference

a cura di / edited by
Adolfo F. L. Baratta
Laura Calcagnini
Antonio Magarò

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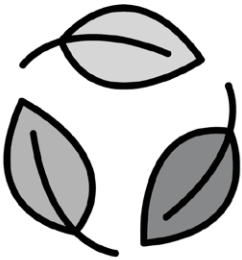

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Atti del V Convegno Internazionale
Il valore della materia nella transizione ecologica del settore delle costruzioni

Proceedings of the 5th International Conference
The value of building materials in the ecological transition of the construction sector

Acta de el V Congreso Internacional
El valor de la materia en la transición ecológica en el sector de las construcciones

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Adolfo F. L. Baratta
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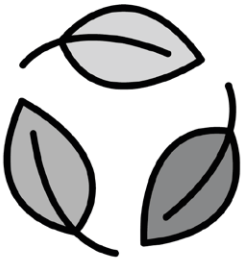

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The value of building materials in the ecological transition of the construction sector

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El valor de la materia en la transición ecológica en el sector de las construcciones

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Esperienze di progetto attraverso processi di “urban mining”

Design experiences through “urban mining” processes

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Summary

The built environment remains the biggest consumer of natural resources globally, with construction and demolition materials among the main sources of waste in developed countries.
Technolgical advances in construction methods and materials alone are not sufficient to offset the environmental impacts of design and construction processes; thus, circular design strategies should be developed and implemented to extend the lifespan of buildings, construction components and materials, keeping resources in use longer and at their highest value.
Stretching this approach, this paper discusses potentials and limitations of urban mining for turning products at the end of their useful life (classified as urban waste) into a source of 'as-new' building products.
Challenging conventional building design approaches, the paper explores alternative construction methods with low-grade materials and interrogates the potential of using urban waste in high performance building construction.
A temporary seaside facility in Liguria (Italy) is presented as an example of urban mining-based design, where type of recoverable materials, distance from the building site, and collection time become additional, and yet critical, design criteria. Environmental and social impacts of urban mining at the city scale and further research opportunities are then discussed as possible venues to increase the uptake of this alternative design approach.

Urban mining, Waste, Circularity,
Temporary building

Introduction

Environmental impacts of buildings remain unsustainable, despite the agreed target of the Paris Agreement and the global imperative to decarbonise the sector by 2050. Contributing about 40% of global energy-related CO2 emissions [UNEP, 2022], the building and construction industry remains one of the highest greenhouse gas emitting sectors globally; it still operates on an obsolete, 'take-make-dispose' linear model [EMF & McKinsey, 2015], where natural resources are unproductively used and disposed in landfills - 60% of 3 billion tons of global construction and demolition (C&D) waste [Ferdous et al., 2021].

Technolgical advances in construction methods and materials alone are not sufficient to offset the environmental impacts of linear design and construction processes. In this gloomy scenario of growing waste and shrink-

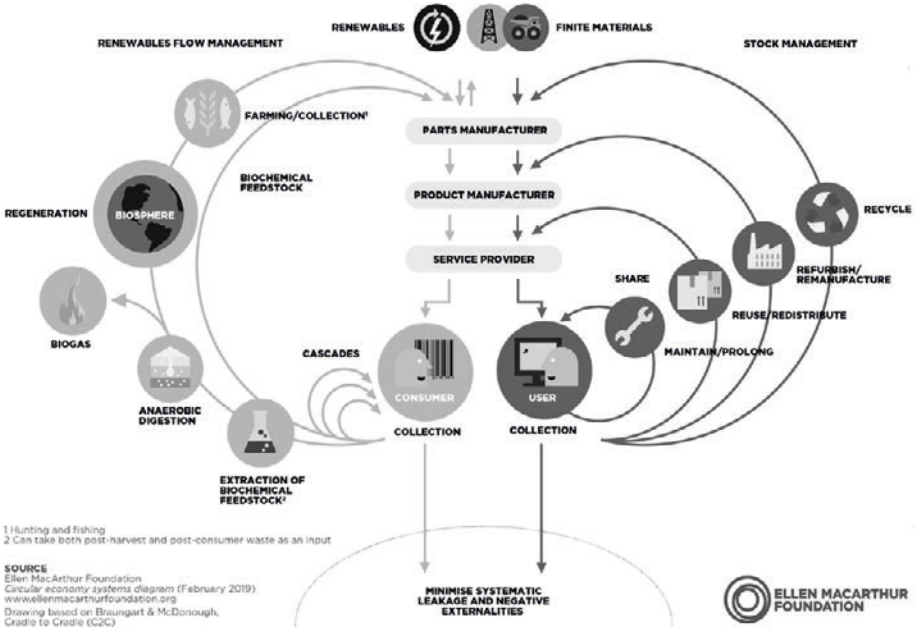

Figure 1. Circular Economy Systems Diagram [Source: Ellen MacArthur Foundation].

ing resources, the circular economy (CE) approach represents a possible way out, by extending the lifespan of buildings and their parts in the value chain, and turning demolition costs into a positive business case [ARUP and EMF, 2020].

The wellknown Ellen MacArthur Foundation's Butterfly Diagram, in Figure 1, illustrates the material flows within a CE as interrelating biological (biosphere) and technical (technosphere) cycles. Building materials and components may span across the two spheres; renewable materials, like rammed earth or untreated timber, can safely return to the biosphere, while human-made products can be 'looped' through reuse, repurpose and adaptation, and eventually remanufactured into new products. Circular design principles translate to the construction industry into solutions to maintain the highest value of building components and systems through mechanisms like extended lifespan or reuse and repurpose.

Even though material recycling is the least favourable option, it remains the most common strategy adopted for transitioning to a CE. In the European Union, for example, the Waste Framework Directive (WFD) set a recovery target to attain 70% recycling of C&D waste by 2020. However, benefits of the CE, span far beyond the waste recycling industry; the full exploitation of circularity in construction requires re-thinking the whole building life cycle to implement the primary CE business models that rely on the expended life of products and building systems through maintenance, upgrades and retrofits, and recycled materials into 'as-new' resources [Stahel, 2016]. This is also recognised by the 2023 revision of the WFD, which is set "to promote direct re-use and design for circularity in order to address waste prevention", and investigates separate collection as a "precondition for improving reuse and recycling". This approach unleashes the potential of municipal waste as a repository of 'as-new' construction materials and components.

In the last decade, the term urban mining (UM) has grown in popularity as a source of secondary resources, becoming a key concept for planning and design of sustainable cities; it looks at anthropogenic materials from urban contexts for replacing virgin resources in production [Arora et al., 2017].

This paper explores the potential of UM as a feeder of the construction industry in an age of resource depletion.

It presents and critically discusses examples of UM projects developed at the Politecnico di Milano, to demonstrate how urban waste can be used for

high performance construction, combined with low environmental impact materials and technological advances.

From designing out to designing with waste

The application of circular principles to buildings implies rethinking the whole design and construction process: optimising the building design and manufacture, and promoting a circular use of material - by maximising reused and bio-based materials while minimising embodied energy and pollutants. The concept of 'design for material optimisation' is not new. In the 1960s, the Berlin-born architect Walter Segal developed a construction method for affordable, self-build housing using standardised, low-value, structural timber components [Rogora and Lo Bartolo, 2013].

The 'Segal Method' leverages the ease of assembly, low maintenance and potential reversibility (due to bolted connections) of a modular, tim-

Figure 2. Module StONE, Abbiategrasso. Structural members in fibreglass coupled with timber elements using the Segal Method ([source: Alessandro Rogora].

ber-frame system that can be directly assembled by building owners with basic carpentry skills. Critical to its success is the additional social and economic value that can be attached to low-grade building materials through simple design strategies.
Overall, the Segal Method is a good example of circular use of resources, through building design and material reuse.
Stretching this concept, could design thinking and technological advances be creatively employed to bring transformational change in construction by using urban waste for high performance buildings? This approach would be well aligned with circular principles and design strategies, as it means up-cycling human made waste, not only through looping but also by re-purposing it with added value in the built environment.

Examples of UM-based design

The conventional approach used by most architects does not usually consider limits other than legal requirements (planning frameworks and building codes) and economic constraints; likewise, the choice of technical solutions does not depends on evaluation of environmental impacts due to the productive process of building materials and component nor the amount of waste generated during construction. However, alternative building practices that rely on a mix of renewable materials and waste have been well documented in the literature [Rogora and Lo Bartolo, 2013].
For example, some do-it-yourself (DIY) projects represent good examples of optimal use of materials, where economic drivers lead to minimized and simplified on-site construction processes as well as use (or reuse) of low-grade materials. The Segal Method mentioned above would meet both goals.
The use of alternative materials by renowned architects has increased their acceptance for construction; celebrated projects such as the Cardboard Cathedral by Shigeru Ban in New Zealand [Barrie, 2014] or The Cave by Monterrey studio Greenfield, with walls of rammed earth and rugged stone [Frearson, 2015] have helped legitimize a different approach to building design and construction. All these projects though, make good use of renewable yet substantially primary materials, like timber, rammed earth, bamboo or cardboard; the environmental benefits of these alternative approaches could be amplified by adopting locally available secondary materials - otherwise classified as 'waste'.

Waste for building innovation

Since its inception, the Sustainable Energy Efficient Design research unit of the Politecnico di Milano has carried out interdisciplinary research on sustainable buildings with low environmental impact technologies: renewable materials with high regeneration rate and urban waste reuse. Within this collaborative environment, UM became a topical area of investigation, shaping the work of researchers and students. The design proposal of Matteo Magazzù [2012] is presented in this paper as an example of a temporary building that does not rely on conventional construction materials and components from industrial manufacturing. Instead, it explores and tests the benefits associated to collecting locally available waste and its re-use potential for construction. Assessing the available waste types and understanding their potential use in a building force the designer to make unconventional morphological and technological choices, considering material limits and time as added variables of the design process. Harvesting materials and their temporary storage, as well as a 'phased' design depending on the availability of waste define the unconventional framework within which UM architecture operates.

The project applies the concepts of reversibility, transience and temporariness to the design of a seaside facility for a tourist location in Liguria, Italy.

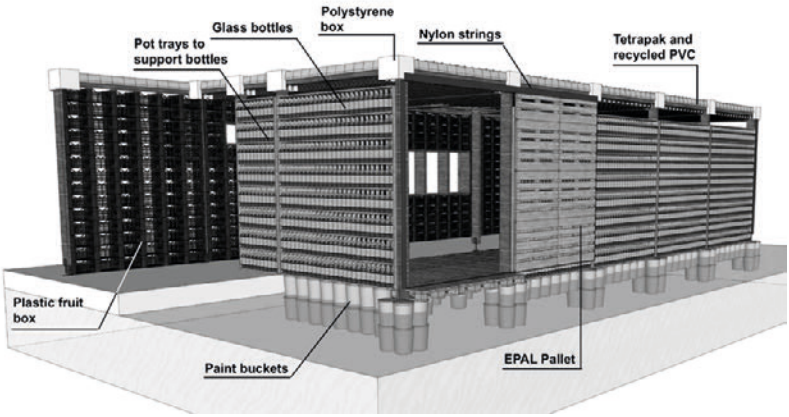

Figure 3. Design proposal of a temporary building made of urban waste [Source: Matteo Magazzù - 2012].

Beyond spatial and functional requirements, the design addresses enviro nmental imperatives (natural resource exploitation, territory depletion, and waste overproduction) by optimizing the use of natural materials and re-using human-made products at the end of their useful life, while achieving adequate thermal comfort through passive design and energy efficiency.
The procurement of secondary construction materials for defining the 'technological units' comprising the building (and responsible for its performance) relies on waste supply from local manufacturers or commercial activities; sand, water and air are also used to add thermal mass or insulation to the shelter. Dry construction of shear layers allows for varying degrees of reversibility of the commercial structure's parts, according to their respective requirements of durability and functional temporariness. Reversible connections and design criteria for material recovery at the end of the components' lifespan ensure easy maintenance and selective demolition at reduced costs. This UM project though, does not compromise on performance; passive solar heating, thermal mass, natural ventilation and evaporative cooling ensure optimal thermal comfort during the opening season. In the design process envisaged in this project, architects become hunters and gatherers of urban waste as well as alchemists capable of transforming waste materials into high performance buildings. After all, a demolished building is made of the same materials of a new building; what changes is their respective degree of entropy. The role of the design process should be precisely that of restoring order. In his book La tecnologia invisibile [1997], Sinopoli describes the 'added value' of good design as the ability to order materials into a building that works effectively, that is cheap, functional and user-friendly.

Discussion

Within the broader UM theoretical framework, the use of waste as a secondary material for construction in mainstream practice raises multiple criticalities and critical issues, which are linked to the very nature of urban waste: heterogeneous and diversely available - both spatially and temporarily. In Europe and Italy, waste is not defined on the basis of a product's obsolescence [98/2008/98/CE; D.lgs. n .152/06], and this status ends when the product meets certain criteria, such as: it is commonly used for specific

purposes; there is a market for it; it meets the technical requirements for a specific use; and it does not lead to negative impacts on the environment or

Prodotto di scarto		Quantità media prodotta (n° pezzi)	Dimensioni		immagine
1	Lattine 33cl	20 al giorno	Altezza 13 cm	Diametro 5 cm	
2	Bottiglia plastica 0,5L	40 al giorno	Altezza 21 cm	Diametro 6 cm	
3	Bicchieri di plastica	30 al giorno	Altezza 8 cm	Diametro 7 cm	
4	Confezioni da 30 uova Scatola da 90 pezzi	1 al giorno	Larghezza 30 cm Altezza 5 cm	Lunghezza 30 cm	
Numero totale delle paninoteche presenti nel Comune: **2**					

Figure 4. Map of locally sorced secondary materials (UM) [Source: Matteo Magazzù - 2012].

human health. Therefore, it is critical to link waste supply and demand, considering what is locally available, and to develop a supporting infrastructure; a waste market for construction would necessarily require an intermediate platform for collection, treatment and supply management [Carli and Rogora, 2017]. This type of infrastructures has been already developed with various degrees of success; from the geo-referenced online platform for waste trading set up in 2007 by Superuse, to more recent initiatives of 'enlightened' cities such as Austin, in the US, whose Materials Marketplace is an online exchange platform to keep materials and products out of landfill [EMF, n.d.].
However, these remain isolated, though commendable, initiatives that are unable to steer the consolidated construction process.
To increase the uptake of UM, the implementation of its inherent design approach at the larger urban scale has been attempted in some projects proposed by architects and researchers.
Opportunities have been identified mostly in retrofit interventions of existing buildings, for energy performance upgrading or addition of functional spaces. In this context, L'ecomostro addomesticato, a project by studio Albori with Rogora [Studio Albori, n.d.], developed for the Padiglione Italia at

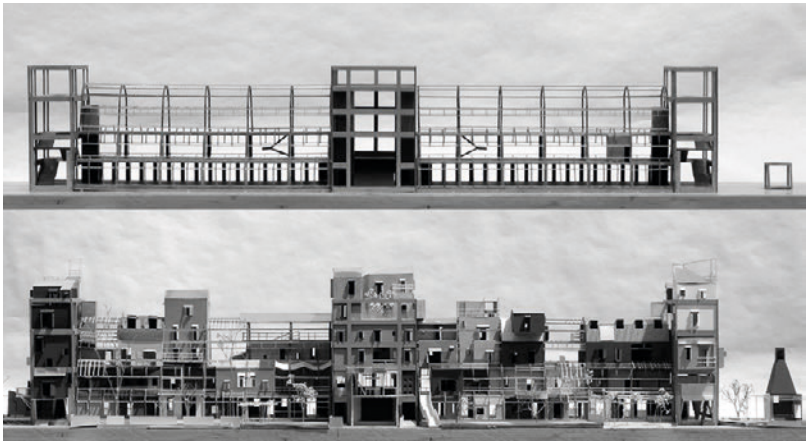

Figure 5. L'ecomostro addomesticato. Existing reinforced concrete structure (top) and integration of new volumes from secondary materials (bottom) [Source: Studio Albori].

2008 Venice Biennale, seeks to demonstrate the re-use and up-cycling potential of abandoned buildings or un-finished structures at the urban fringe - called 'ecomonsters' and intended for demolition (Figure 5).
The unfinished and never-used structure of a railway station, designed by Aldo Rossi and Gianni Braghieri outside Milan, is approached in this project as oversized, value-added urban waste due to its strategic location. In addition to the averted demolition of the reinforced concrete structure, the project unleashes social benefits of low-cost housing and community facilities as well as environmental benefits of urban waste re-use as a secondary construction material, which defines the incremental and dynamic nature of this project.

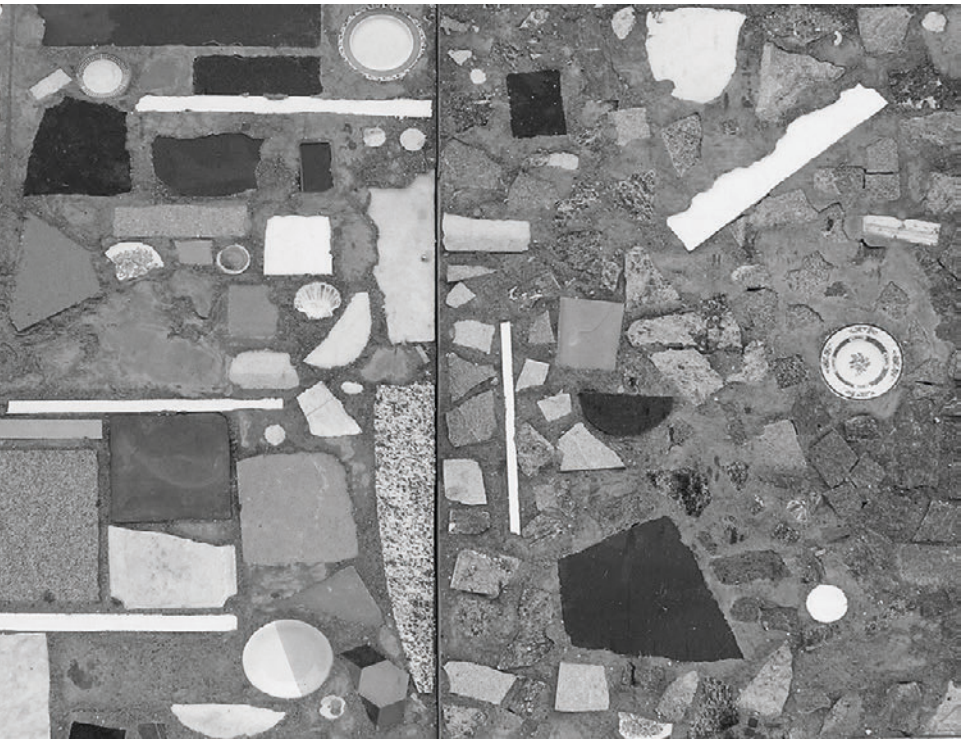

Figure 6. Concrete slab details of the residential complex on the site of ex – Ceramica Lago, in Laveno (Varese), 2008 [Source: Studio Albori].

A 'quick and dirty' evaluation of the thermal performances of the tetrabrik walls of the 1:1 prototype was developed ad hoc, showing a suitable pathway to overcome stringent building code rules.

Conclusions

Using secondary materials from UM deeply shifts design paradigms, reducing the alternative options available for each project, as environmental imperatives and time become variables of the construction process.

These two elements could appear contradictory in a society driven by increased speed and uncontrolled resource consumption; however, they represent critical concepts of the discourse on sustainability, which necessarily draws from a respectful understanding of natural time flows and resource limitations.

While we argue that environmental design cannot substantiate outside these paradigms, the UM design propositions discussed in this paper demonstrate how secondary materials do not necessarily reduce the project quality, which, rather, depends on the ability and environmental sensitivity of the designer.

Furthermore, reintroducing waste in construction not only deeply impacts the design process but also its outputs, as it generates opportunities for unfamiliar sensorial engagement of the end-users through innovative material and spatial solutions. When creatively and expertly crafted, this may generate added value, as demonstrated in the unbuilt project of a residential complex on the site of ex – Ceramica Lago, in Laveno (Figure 6). Here, the designers experiment the use of pottery shards for the predalles concrete slabs; visible at the intrados of the slab, waste becomes a statement of uniqueness. Undeniably, multiple social, technical and economic factors exist that may limit the uptake of UM strategies and the re-use of urban waste as a secondary construction material; for example, regulatory issues, the need for a complete reorganisation of the building site, end-user distrust and resistance to change, or the lack of skilled manpower. All these reasons would justify easier design and construction pathways, especially in a market-driven building sector.

However, sustainability requires courageous collective choices for the common good, where social and environmental benefits must be accounted for to build a solid business case for an actually sustainable built environment.

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Il V Convegno Internazionale Recycling, dedicato a "Il valore della materia nella transizione ecologica del settore delle costruzioni" si è tenuto a Roma il 26 maggio 2023, confermandosi come uno dei principali luoghi di confronto tra accademici e *stakeholders*. Il Comitato Scientifico, composto da docenti ed esperti provenienti da 24 Atenei internazionali, distribuiti su 4 Paesi e 3 continenti, ha selezionato i migliori contributi tra quelli pervenuti secondo la procedura *double blind peer review*. Come di consuetudine, i contributi sono stati suddivisi nelle tre sezioni del Convegno Internazionale: "Saggi", "Ricerche" e "Architettura". La raccolta degli atti ha come obiettivo la definizione dello stato dell'arte del riciclaggio nel settore delle costruzioni, oltre a fotografare la direzione verso la quale il mondo della ricerca scientifica si sta orientando. La moltitudine di punti di vista che caratterizza il presente volume è, probabilmente, il suo maggiore valore, restituendo un profilo innovativo e creativo sul tema.

The 5th International Conference Recycling, dedicated to "The value of building materials in the ecological transition of the construction sector" was held in Rome on May 26, 2023 confirming its status as one of the main venues for dialogue between academics and stakeholders. The Scientific Committee, consisting of professors and experts from 24 international universities, spread over 4 countries and 3 continents, selected the best papers among the ones received according to the double blind peer review. As usually, the papers were divided into the three sections of the International Conference: 'Essays', 'Research' and 'Architecture'. The aim of the proceedings is to define the state of the art of recycling in the construction sector, as well as to take a framework of the direction in which the world of scientific research is heading. The multitude of vievpoints that characterises this volume is probably its greatest value, providing an innovative and creative profile on the subject.

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